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[Abstract]

[Problem to be solved by the Invention]

The temperature of a ceramic heater 1, in a temperature range of 200°C or higher, can be precisely measured by means of a temperature detection means 6, such as a thermocouple.

[Means for Solving the Problem]

A resistance heating element 4 is buried in a ceramic body 2 made of an insulating ceramic of which the main component is any one type from among alumina, aluminum nitride, silicon nitride and boron nitride, wherein the carbon content is 500 ppm, or less, and wherein the volume specific resistance in the temperature range of 200°C or higher is 10^8 Ω·cm or greater, and wherein one main surface of the above described ceramic body 2 is used as a mounting surface 3 so that a temperature detection means 6 for measuring the temperature of the above described mounting surface 3 is inserted in a surface other than this mounting surface 3 and, thereby, ceramic heater 1 is formed.

[Scope of Claim for Patent]

[Claim 1] A ceramic heater wherein one main surface of a ceramic body in which a resistance heating element is buried is used as a mounting surface of an object to be heated and wherein a temperature detection means for

measuring temperature of said mounting surface is inserted in a surface other than said mounting surface, wherein said ceramic body is made of ceramic of which a main component is any of alumina, aluminum nitride, silicon nitride, or boron nitride, of which the carbon content is 500 ppm or less and of which the volume specific resistance in a temperature range of 200°C or higher is not less than 10^8 Ω·cm.

[Detailed Description of the Invention]

[0001]

[Technical Field to which the Invention Pertains]

The present invention relates to a ceramic heater provided with a temperature detection means, such as a thermocouple, in particular, to a ceramic heater used in a film formation device, such as for CVD, PVD, or sputtering, or used in an etching device, and such a ceramic heater is specifically favorable as a ceramic heater for a semiconductor manufacturing device.

[0002]

[Prior Art]

A ceramic heater for supporting a wafer and for heating the wafer to a predetermined processing temperature conventionally has been utilized in a film formation device, such as for PVD, CVD, or sputtering, for forming a thin film on a semiconductor wafer (hereinafter referred to as

wafer), or in an etching device for microscopic processing, which are used in the manufacturing processes for semiconductor devices.

[0003]

A ceramic heater of such a type is provided with a resistance heating element 14 buried in a ceramic body 12, of a disk form, as shown in Figs. 5(a) and 5(b), and the upper surface of the above described ceramic body 12 is used as a mounting surface 13 for supporting and heating an object W to be heated, such as a wafer, and power supply terminals 15 for supplying voltage to the above described resistance heating element 14 are connected to the lower surface of the above described ceramic body 12. Further, a wafer W is placed on the above-described mounting surface 13 and the object W to be heated is heated to a predetermined processing temperature by supplying voltage to resistance heating element 14 which, then, emits heat.

[0004]

In addition, in a variety of processes, the precision of processing is closely related to the temperature of the object W to be heated and, therefore, a temperature detection means 16, such as a thermocouple, is inserted into the above described ceramic body 12 from the lower surface so that the temperature of the mounting surface 13 is measured by means of this temperature detection means 16,

and the amount of current supplied to resistance heating element 14 is controlled so as to maintain the temperature of the object W to be heated at a constant level based on the measurement data (see Japanese unexamined patent publication H6 (1994)-176855).

[0005]

In addition, ceramic heater 11 utilized in a film formation device or an etching device is exposed to halogen-based gases, or plasma, having a high corrosiveness and, therefore, the above described ceramic body 12 is required to be formed of a ceramic having excellent resistance to corrosion by halogen-based gases, and having resistance to plasma resulting in the usage of a ceramic of which the main component is alumina, silicon nitride or aluminum nitride.

[0006]

Then, in recent years the size of ceramic heaters 11 has rapidly increased as has the size of wafers, and, as for the manufacture of such a ceramic heater 11, a metal wire for forming resistance heating element 14 is, for example, buried in a ceramic powder, which may be of a variety of types, so as to be unified in the ceramic through sintering by means of a hot press method and, thereby, ceramic body 12, of a disk form provided with buried resistance heating element 14, is manufactured, or

conductive paste for forming resistance heating element 14 is printed on a green sheet, which may be made of one of a variety of types of ceramic materials, in a predetermined heating pattern and, after that, this heating pattern is covered with another green sheet so as to form a green sheet layered body and, then, this green sheet layered body is integrated through sintering by means of a hot isostatic press (HIP) method after pre-sintering and, thereby, ceramic body 12, in a disk form provided with buried resistance heating element 14, is manufactured. A mounting surface 13 is formed by carrying out a polishing process, or the like, on one main surface of a ceramic body 12 gained according to these methods, and two recesses 12a connected to resistance heating element 14 and a recess 12b extending to the vicinity of mounting surface 13, respectively, are created in the other main surface so that power supply terminals 15 are connected through recesses 12a while temperature detection means 16 is connected through recess 12b and, thereby, the ceramic heater is manufactured.

[0007]

[Problem to be solved by the Invention]

When the above described ceramic heater 11 is heated, up to a temperature of 200°C or higher, however, a problem arises wherein measurement data irregularities occur in

temperature detection means 16 so that the temperature of mounting surface 13 cannot be measured in a precise and stable manner. Therefore, when such a ceramic heater 11 is used and a film formation process is applied to the object W to be heated at a temperature of 200°C, or higher, the film quality and thickness differ from one film to another that is formed because mounting surface 13 cannot be stably heated at a predetermined temperature and, in addition, when an etching process is carried out on the object W to be heated, a stable film formation process, or etching process, cannot be carried out such that the depth of etching differs from one etching process to another.

[0008]

Therefore, the present inventors have carried out research concerning the cause of the occurrence of irregularities in measurement data from temperature detection means 16 in the temperature range of 200°C, or higher, and, then, have discovered that the volume specific resistance of the ceramic forming ceramic body 12 is quite low, so that this drop in volume specific resistance allows the occurrence of irregularities in measurement data from temperature detection means 16.

[0009]

That is to say, the volume specific resistances of ceramics tend to become lower as temperature increases, and

carbon in the sintering atmosphere easily mixes into a ceramic body 12 manufactured according to a hot press method, or HIP method, as described above. It is considered that, in the case wherein the amount of such carbon is great, the volume specific resistance of ceramic body 12 is lowered, and when the ceramic is heated to a temperature of 200°C, or higher, a microscopic current easily flows from resistance heating element 14 to temperature detection means 16. Then, in the case that temperature detection means 16 is a thermocouple, thermocouples allow temperature measurement, using a potentiometer, by detecting electromotive force occurring between the contacts due to a temperature gap wherein different types of metals are connected. In the case of a K thermocouple, for example, change in electromotive force in response to an increase in temperature of 1°C is extremely small, being of approximately 40 μV. Therefore, in the case that a microscopic current of approximately several μA flows from resistance heating element 14, the potentials of the contacts point of the thermocouple change so as to cause irregularities in measurement data and, furthermore, it is considered that a current also flows into the potentiometer for measuring the electromotive force of the thermocouple so that a value differing from the actual temperature is shown.

[0010]

[Means for Solving Problem]

Therefore, the present invention is provided in view of the above described problem so that a ceramic heater wherein one main surface of a ceramic body in which a resistance heating element is buried is used as a mounting surface of an object to be heated and wherein a temperature detection means for measuring the temperature of the above described mounting surface is inserted into a surface other than this mounting surface is characterized in that the above described ceramic body is formed of an insulating ceramic of which the main component is any one type from among alumina, aluminum nitride, silicon nitride and boron nitride, and of which the carbon content 500 ppm or less, and of which the volume specific resistance in a temperature range of 200°C or higher is not less than 10^8 Ω·cm.

[0011]

[Operation]

According to the present invention, a ceramic body for forming a ceramic heater is made of an insulating ceramic having a volume specific resistance of not less than 10^8 Ω·cm in a temperature range of 200°C or higher, and, therefore, a microscopic current can be prevented from flowing from the resistance heating element to the

temperature detection means even when the heater emits heat up to a temperature of 200°C or higher, so that the temperature detection means does not generate irregularities in measurement data, and the temperature of the mounting surface can be precisely and stably measured.

[0012]

In addition, according to the present invention, the above-described ceramic body is made of an insulating ceramic of which the main component is any one type from among alumina, aluminum nitride, silicon nitride and boron nitride, and the carbon content in the above described insulating ceramic is 500 ppm or less, and, therefore, the volume specific resistance becomes not less than 10^8 Ω·cm in a temperature range of 200°C or higher, and, furthermore, the ceramic is excellent in resistance to corrosion by halogen-based gases and in resistance to plasma so that a ceramic heater that can be utilized for a long period of time can be gained.

[0013]

[Embodiments of the Invention]

The embodiments of the present invention are described in the following. Fig. 1(a) is an oblique perspective view showing one example of a ceramic heater of the present invention and Fig. 1(b) is a cross sectional view along line X-X of Fig. 1(a).

[0014]

This ceramic heater 1 is formed of a ceramic body 2 in a disk form and this ceramic body 2 is formed of an insulating ceramic: of which the main component is any one type from among alumina, aluminum nitride, silicon nitride and boron nitride; of which the carbon content is 500 ppm, or less; and of which the volume specific resistance in a temperature range of 200°C or higher is not less than 10^8 Ω·cm.

[0015]

In addition, a membranous resistance heating element 4 having a heating pattern as shown in Fig. 2(a) is buried in the above described ceramic body 2, and a mounting surface 3 for mounting an object W to be heated is provided on the upper surface of the above described ceramic body 2 while power supply terminals 5, respectively, are connected through two recesses 2a, which lead to the above described resistance heating element 4 so as to make an electrical connection by means of brazing or the like, are provided in the lower surface of the above described ceramic body 2. Here, the heating pattern of the above described resistance heating element 4 is not limited to the pattern shown in Fig. 2(a) but, rather, may be a pattern in a spiral form, as shown in Fig. 2(b), and may have any pattern form that allows mounting surface 3 to be uniformly heated. In

addition, not only membranous resistance heating element 4 but, also, a metal wire can be used and, in the case that a metal wire is used, a wound wire in a spiral form may, for example, be provided in the form of a buried heating pattern, as shown in Figs. 2(a) and 2(b).

[0016]

In addition, a recess 2b that leads to the vicinity of mounting surface 3 is provided in the lower surface of the above-described ceramic body 2 and a temperature detection means 6, such as a thermocouple, is inserted into this recess 2b. Here, according to this measure of inserting temperature detection means 6, threading is provided to the inner wall surface of recess 2b so that temperature detection means 6 is secured with a screw or a cylinder (not shown) is connected in the above described recess 2b by means of adhesion using glass or the like, brazing, fixing with screws, diffusion bonding or the like, so that temperature detection means 6 can be connected to this cylinder by means of fixing with screws or by adhesion using glass or the like. In addition, though in the example shown in Fig. 1, temperature detection means 6 is inserted into the lower surface of ceramic body 2, the temperature detection means may be inserted into the side surface of ceramic body 2.

[0017]

Then, when object W to be heated is mounted on mounting surface 3 of this ceramic heater 1 and a voltage is applied to resistance heating element 4 so that heat is emitted, object W to be heated can be uniformly heated to a predetermined process temperature and a microscopic current can be prevented from flowing into temperature detection means 6 from resistance heating element 4 because the volume specific resistance of ceramic body 2 is not less than 10^8 Ω·cm when heated to a temperature of 200°C or higher, and, therefore, the temperature of mounting surface 3 can be precisely measured by means of the above described temperature detection means 6 so that the power applied to resistance heating element 4 can be controlled in order to maintain the temperature of object W to be heated at a constant level based on measurement data from temperature detection means 6.

[0018]

In addition, the above-described ceramic body 2 is made of a ceramic of which the main component is any from among alumina, aluminum nitride, silicon nitride and boron nitride having an excellent resistance to corrosive halogen-based gases and plasma used in a film formation device or in an etching device, and, therefore, ceramic heater 1 can be used for a long period of time. In particular, a ceramic of which the main component is

aluminum nitride or boron nitride has an excellent heat conductivity from among the above described ceramics so that the rate of temperature increase or of cooling of ceramic heater 1 can be improved and object W to be heated can be more uniformly heated.

[0019]

Here, as for the insulating ceramic of which the main component is any one type from among alumina, aluminum nitride, silicon nitride and boron nitride and of which the carbon content is 500 ppm or less, an insulating ceramic of which the main component is any one type from among alumina, aluminum nitride, silicon nitride and boron nitride and of which the carbon content is 500 ppm or less, that contains a component that does not exhibit conductivity as an assistant component can be used.

[0020]

As for an insulating ceramic of which the main component is alumina, a ceramic of which the alumina content is not less than 98 wt.%, preferably not less than 99 wt.% and more preferably not less than 99.5 wt.%, that contains a sintering assisting agent, such as SiO_2, MgO, CaO, TiO_2, or the like, as another assistant component can be used and as for an insulating ceramic of which the main component is aluminum nitride, a ceramic of which the aluminum nitride content is not less than 91 wt.%,

preferably not less than 99 wt.% and more preferably not less than 99.8 wt.%, that contains Y_2O_3 or an oxide of a rare earth element, such as of Er, as another assistant component can be used. In addition, as for an insulating ceramic of which the main component is silicon nitride, a ceramic of which the silicon nitride content is not less than 90 wt.%, preferably not less than 95 wt.% and more preferably not less than 98 wt.%, that contains Al_2O_3 and Y_2O_3 as other assistant components can be used, and as for an insulating ceramic of which the main component is boron nitride, a ceramic of which the boron nitride content is not less than 95 wt.%, preferably not less than 98 wt.% and more preferably not less than 99 wt.%, that contains B_2O_3 or the like as another assistant components can be used.

[0021]

In addition, an insulating ceramic substantially made of only one type of either alumina or aluminum nitride, with the remaining portion being carbon of no greater than 500 ppm and with other impurities, can be used and, as for such a ceramic, a ceramic of which the alumina or aluminum nitride content is not less than 99.8 wt.% can be used. In particular, an aluminum nitride ceramic of a high purity of which the aluminum nitride is not less than 99.8 wt.% is suitable for use in ceramic body 2 because of high thermal conductivity and outstanding excellence in resistance to

corrosion and resistance to plasma due to the small number of grain boundary layers.

[0022]

Then, it is important for the carbon content in these insulating ceramics to be 500 ppm or less.

[0023]

This is because, in the case that the carbon content becomes greater than 500 ppm, the volume specific resistance of the insulating ceramics in the temperature range of 200°C or higher becomes less than 10^8 Ω·cm, a precise temperature measurement cannot be carried out by temperature detection means 6.

[0024]

On the other hand, as for resistance heating element 4 buried in the above described ceramic body 2, a metal, such as tungsten (W), molybdenum (Mo), nickel (Ni), platinum (Pt), gold (Au), silver (Ag), or an alloy of these metals, or nitrides or carbides of an element in group 4a or 5a of the periodic table can be used so that a material which is slightly different from the insulating ceramic forming ceramic body 2 in thermal expansion may be selectively used.

[0025]

In addition, as for the material forming power supply terminals 5, tungsten (W), molybdenum (Mo), nickel (Ni), or

a Fe-Co-Ni alloy can be used so that a material which is slightly different from the insulating ceramic forming ceramic body 2 in thermal expansion may be selectively used in the same manner as for resistance heating element 4.

[0026]

In order to manufacture such a ceramic heater 1, a solvent, a binder, and the like, is added to, and mixed with, the above described ceramic material so as to prepare a slip and, then, a plurality of ceramic green sheets are prepared by means of a tape formation method, such as a doctor blade method. Then, a conductive paste for forming a resistance heating element is spread on top of a plurality of layered ceramic green sheets in a heating pattern as shown in Fig. 2, for example, by means of a screen printing method and, after that, the remaining ceramic green sheets are layered so as to cover the above described heating pattern and a green sheet layered body is formed. After that, the above described green sheet layered body is sintered and, thereby, ceramic body 2 in which resistance heating element 4 is buried is manufactured, wherein it is necessary for the ceramic body and the resistance heating element to be unified through sintering by means of a hot isostatic process (HIP) method under the conditions wherein they are buried in Al_2O_3 powder, AlN powder or Si_3N_4 powder after they have been

sintered in a nitrogen and/or hydrogen atmosphere, or in a vacuum during sintering.

[0027]

That is to say, though in the case that a HIP process is directly carried out on ceramic body that has been pre-sintered, the carbon in the sintering atmosphere enters into ceramic body 2 so as to lower the volume specific resistance at a temperature of 200°C or higher, the entrance of carbon can be prevented by sintering the ceramic body buried in the above described ceramic powder so that the volume specific resistance at a temperature of 200°C or higher, can be prevented from becoming less than 10^8 Ω•cm.

[0028]

In addition, as for another method of manufacturing ceramic body 2, a mud made of a ceramic, from among a variety of ceramics, is dried and granulated so as to be converted to granules and a metal wire wound in a spiral form is buried in these granules so as to form the heating pattern shown in Fig. 2 and, thereby, ceramic body 2, in which resistance heating element 4 is buried, can be manufactured by sintering and unifying the granules and the metal wire according to a hot press method. Here, at the time of sintering and unification according to this hot press method, it is necessary to sinter and unify the

granules and the metal wire under the conditions wherein they are buried in Al_2O_3 powder, AlN powder or Si_3N_4 powder.

[0029]

And, a polishing process or the like is carried out on one of the main surfaces of ceramic body 2 that has been gained according to one of these methods, so as to form mounting surface 3, and, then, two recesses 2a leading to resistance heating element 4 as well as a recess 2b extending to the vicinity of mounting surface 3, respectively, are provided in the other main surface so that power supply terminals 5 are connected through recesses 2a by means of brazing or the like, and temperature detection means 6 is connected through recess 2b, and, thereby, ceramic heater 1 of the present invention can be gained.

[0030]

Next, another embodiment of the present invention is described. Fig. 3 shows a structure that is almost the same as in Fig. 1(b) and another internal electrode 7 is buried between mounting surface 3 and resistance heating element 4 so that this internal electrode 7 is utilized as, for example, an electrode for electrostatic adsorption and a voltage is applied between the above described internal electrode 7 and object W to be heated mounted on mounting surface 3 and, then, a Coulomb force due to inductive

polarization or a Johnson-Rahbek force due to a microscopic leak current is effected between object W to be heated and internal electrode 7 so that object W to be heated can be electrically adsorbed and fixed on mounting surface 3 and, in addition, the above described internal electrode 7 is used as an electrode for generating plasma so that high-frequency power is applied between the internal electrode and an electrode for plasma generation, which is installed separately and, thereby, plasma can be generated.

[0031]

[Embodiments]

Here, ceramic heaters are manufactured of aluminum nitride ceramics of a high purity, having different carbon contents, and an experiment was carried out wherein the existence of irregularities in measurement data is checked for when these ceramic heaters are heated to a predetermined temperature, which is measured by a thermocouple.

[0032]

In the present experiment, ceramic heaters 1 having an external diameter of 200 mm and a thickness of 12 mm, shown in Fig. 1, are manufactured wherein recesses 2b (external diameter of 2 mm and depth of 7 mm) for allowing insertion and fixing of thermocouples as temperature detection means 6 are provided in the lower surfaces of

ceramic bodies 2 and, after that, K-type thermocouples (made by Yamari Industries, Limited), having a stripped wire diameter of 1 mm, are connected in these recesses 2b through fixing with screws. In addition, the AlN content of the aluminum nitride ceramic of a high purity for forming ceramic bodies 2 is approximately 99.8 wt.% and resistance heating elements 4 are made of tungsten, and power supply terminals 5 are formed of a Fe-Co-Ni alloy, respectively.

[0033]

Then, these ceramic heaters 1 are placed within a heating furnace, of which the temperature within the furnace has a dispersion of ± 2°C, so that ceramic heaters 1 are heated to 200°C under the conditions wherein a direct current 100 V is applied to one of power supply terminals 5 of the above described ceramic heaters 1 and, then, the ceramic heaters are evaluated such that ceramic heaters wherein the temperature difference between the temperature of the heating furnace and the thermocouple is within 4°C are given a O symbol and ceramic heaters wherein the temperature difference between the temperature of the heating furnace and the thermocouple is not less than 4°C are given a × symbol.

[0034]

Here, Fig. 4 shows the relationship between the

volume specific resistances of aluminum nitride ceramics of a high purity having different carbon content and temperature, while Table 1 shows the experimental results, respectively.

[0035]

[Table 1]

Table 1

	Carbon content PPM	Theoretical density	Volume specific gravity	Relative density %	Volume specific resistance 200°C (Ω cm)	Measurement result
1	84	3.260	3.180	97.5%	7.0.E+11	
2	184	3.260	3.186	97.7%	3.0.E+11	O
3	267	3.260	3.200	98.2%	9.0.E+10	O
4	394	3.260	3.210	98.5%	1.0.E+10	O
5	460	3.260	3.217	98.7%	8.0.E+08	O
*6	638	3.260	3.214	98.6%	8.0.E+07	X
*7	876	3.307	3.268	98.8%	9.3.E+05	X
*8	1030	3.276	3.258	99.4%	5.5.E+05	X
*9	1345	3.260	3.248	99.6%	9.0.E+03	X

The * symbol is attached to ceramic heaters outside of the scope of the present invention.

[0036]

As a result of this, in the case that the volume specific resistance of the aluminum nitride ceramic is not less than 1×10^8 Ω·cm at a temperature of 200°C, the difference between the temperature of the heating furnace and the temperature of thermocouple becomes 4°C or less, and it is found that a precise temperature measurement is

possible without irregularities in the measurement data of the thermocouple.

[0037]

Then, in order to make the volume specific resistance of aluminum nitride ceramic not less than 1×10^8 Ω·cm at a temperature of 200°C or higher, the carbon content in the aluminum nitride ceramic should be 500 ppm or less, as shown in Fig. 4 and in Table 1 and, in particular, it is found that a precise temperature measurement is possible by means of a thermocouple up to approximately 700°C with respect to sample No. 1 having a carbon content of 84 ppm.

[0038]

Here, though in the present embodiment, only examples wherein aluminum nitride ceramic of a high purity is used for ceramic bodies 2 are shown, the same tendency is seen in other insulating ceramics wherein the carbon content is not greater than 500 ppm.

[0039]

[Effects of the Invention]

As described above according to the present invention, in a ceramic heater wherein one main surface of a ceramic body in which a resistance heating element is buried is used as a mounting surface and temperature detection means for measuring the temperature of the above described mounting surface is inserted into a surface other than this

mounting surface, the above described ceramic body is formed of an insulating ceramic: of which the main component is any one type from among alumina, aluminum nitride, silicon nitride and boron nitride; of which the carbon content is 500 ppm or less; and of which the volume specific resistance in a temperature range of 200°C or higher is not less than 10^8 Ω·cm and, thereby, a microscopic current can be prevented from flowing into the temperature detection means from the resistance heating element even when the ceramic heater emits heat so that the temperature of the mounting surface can be precisely measured in a stable manner for a long period of time even at a temperature of 200°C or higher.

[0040]

Accordingly, when a ceramic heater of the present invention is used, the temperature of the mounting surface can be maintained at a constant level of a predetermined process temperature and, therefore, when this is used in a film formation device, for example, of a semiconductor device manufacturing process, a thin film of a constant thickness can be uniformly formed even when film formation is repeated and, in the case that ceramic heater is used for an etching process, etching can process an object with a constant depth even when etching is repeated.

[0041]

In addition, the ceramic heater of the present invention has an excellent resistance to highly corrosive halogen-based gases and plasma, and therefore, the ceramic heater can be utilized for a long period of time.

[Brief Description of the Drawings]

Fig. 1(a) is an oblique perspective view showing one example of a ceramic heater of the present invention; Fig. 1(b) is a cross sectional view along line X-X of Fig. 1(a);

Fig. 2(a) is a diagram showing the form of a heating pattern of a resistance heating element buried in the ceramic heater of Figs. 1(a) and 1(b); Fig. 2(b) is a diagram showing the form of another heating pattern;

Fig. 3 is a cross sectional view showing another example of a ceramic heater of the present invention;

Fig. 4 is a graph showing the relationships between the volume specific resistance and the temperatures of high purity aluminum nitride ceramic with different carbon content;

Fig. 5(a) is an oblique perspective view showing a ceramic heater according to a prior art; and Fig. 5(b) is a cross sectional view along line Y-Y of Fig. 5(a).

[Explanation of Symbols]

1, 11…ceramic heaters

2, 12…ceramic bodies

3, 13…mounting surfaces

4, 14…resistance heating elements

5, 15…power supply terminals

6, 16…temperature detection means

W…object to be heated

Translation of Fig. 4

Longitudinal axis: volume specific resistance $\Omega \cdot cm$

Lateral axis: 1000/temperature K